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Water access transformations: Metrics, infrastructure, and inequities

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Abstract
Scholarship on water insecurity has carried over an important insight from studies of food insecurity: Insecurity often occurs in the midst of plenty, and water insecurity is therefore better characterized by inaccessibility than by scarcity. Access to clean, adequate, and reliable water is, however, more challenging to systematize than access to food. Water is fluid and protean, and only when it is safely stored can people pretend to own it. In this paper, I make a case for the centrality of infrastructure – systems of water storage and transport – to water security. Equitable access to water often depends on technologies that protect, filter, and distribute water; it also depends on social arrangements that protect the least powerful from exclusion. I analyse two water infrastructure projects in Ethiopia, one a project to protect village water supplies and the other a large hydroelectric dam. The project to protect springs used by villagers for household water supply had the unintended effect of limiting access to those who could pay fees to a water committee. The dam harnessed water to produce electricity and supply irrigated plantations, but deprived downstream communities of water for farming. Water infrastructure can have far-reaching implications for water access, both for better and for worse. It is often instrumental in securing one group's access to water at the cost of another's.

Introduction

On a recent visit to Ethiopia I had the good fortune of staying in a five-star hotel in Addis Ababa. My room afforded a view of townhouses with well-maintained gardens; the faucets in the bathroom provided abundant, clean water. For friends across town, water supply was erratic; days, sometimes weeks, passed without water in the pipes. People in their neighbourhood had devised workarounds: leaving taps turned on and buckets at the ready in case water should arrive in the night. In seasons when rainfall in the Omo basin was lower than expected, the city experienced rolling black-outs. Power supply too depended on water – in this case, the reservoir behind the Gibe III dam on the River Omo, which was said to provide half the electricity on the national grid (Salini 2016). In the luxury hotels, diesel generators would supply electricity when the power cut off. Others would get by with flashlights, or candles, or in darkness.

In 2015 Unicef and the World Health Organization declared that Ethiopia had met its Millennium Development Goal (MDG) for safe drinking water. Between 1990 and 2015 the proportion of the population with access to safe drinking water had risen from 14 to 57 per cent (Joint Monitoring Program 2015). Safe drinking water, according to the MDGs, was defined as water drawn from "improved sources": those in which water was protected from contamination by pipes or concrete structures. But as Bradley & Bartram (2013) note, "improved sources" do not always provide reliable or clean water. The framers of the MDGs had opted for an easily measurable indicator; but as often, there is a trade-off between ease of measurement and the fidelity of the metric to the construct of interest.

Water security is a complex construct which can refer to a wide range of things at the scale of households, river basins, or the globe (cf. Lankford et al. 2013; Wutich & Brewis 2014). In the sense in which I use the term (following the lead of scholars of food security, e.g. Webb et al. 2006; Barrett 2010) water security is shorthand for secure *access* to water. At an individual or household level, this implies at least having enough to drink and wash with; at higher scales, sufficiency of supply is harder to define, as it depends on the uses to which water is put – to grow crops, to generate electricity, to serve cities or sustain ecosystems – which must be balanced against each other. Regardless of the scale, however, it makes more sense to speak of access to water than ownership of water, because only in exceptional cases (e.g. bottled water or a private lake) do people pretend to own the stuff (Bakker 2003). Security implies access that is stable in the recent past and likely to continue in future. The concept of water security resonates today because stable and continuing states are increasingly desired in our precarious and unpredictable world.

We must also, however, bear in mind the question, *security for whom*? There is no reference group specified in the term, and one group's water security has often been achieved at the cost of another's (Srinivasan et al. 2017; Zeitoun 2011). One community may attempt to wrest control over water from another, as the city of Los Angeles did to the people of the Owens Valley over the course of the 20th century (Reisner 1993); or access may be shared out through complex systems of turn-taking, as in the municipal water system of Mumbai (Anand 2017). Or, as in Addis Ababa, the sharing may be done covertly, in ways that make it difficult to contest.

One promising avenue for understanding distributional issues related to water security is the study of water infrastructure. Infrastructure is important because it is through installation of such things as pipes, dams and levees that natural flows of water are channeled to social ends. They do so not only by altering physical flows but also, crucially, through the social arrangements that are introduced along with them. These social arrangements may be relatively informal and opportunistically enforced, or they may be codified as rules that are overseen by bureaucracies of various kinds – including water committees, utility boards, ministries, and judiciaries. In moments of rapid change, when new infrastructure is installed, new social arrangments for water access are worked out. For this reason, even the simplest technologies – such as taps or water meters – may be highly visible and contentious (Larkin 2013; von Schnitzler 2008; Anand 2011). They arouse passions because claims to ownership of water infrastructure have implications for water access. In the language of social studies of science and technology, infrastructural projects are always technopolitical projects; the technical and political are two sides of the same coin (Mitchell 2002).

In this essay I consider lessons from two cases of infrastructure change that I have studied in Ethiopia. The first concerns an intervention by an NGO to protect village water supplies from contamination. The second focuses on a large dam and its implications for multiple groups of stakeholders, including city dwellers and farmers living in the floodplain downstream. In both cases, the interventions had mixed effects, including substantial negative impacts on the livelihoods and water security of already marginalized people. In the conclusion I ask whether attention to the processes involved in these case studies might help to predict and potentially to ameliorate the outcomes of water infrastructure projects in future. Before I proceed, however, some remarks on measurement of water security are in order.

1. Measuring access to water

Early investigations of water security drew heavily on research regarding food access. Amartya Sen, in his classic essay on poverty and famines, noted that famines are typically caused not by food being unavailable, but by it being inaccessible. When Sen was young, famine had struck his native Bengal. "While the famine killed millions," he wrote later, "Bengal was producing the largest rice crop in history in 1943." (Sen 1981: 77-8). The reasons for famine in general, he argued, were to be sought not primarily in scarcity, but in social arrangements governing property. Access to food constitutes "one of the most primitive property rights" (Sen 1981: 45). The rights are most easily operationalized in terms of prices, and entitlement may then be computed as purchasing power (the ability of a person or group to buy enough food to meet their needs). The biggest access barrier is poverty.

Carrying this approach over to water is not straightforward. The access principle holds: it is inaccessibility rather than unavailability of water that is the principal constraint on water security. But since in most world areas water remains a common property resource (albeit a highly contested one), access barriers are often determined not so much by prices as by such things as geographical variation in supply, quality and reliability, and ownership of (or access to) water infrastructure. Assessing the height of barriers therefore requires attention to locally variable conditions that influence water access. This may include poverty, but also other aspects of power/powerlessness besides.

Documenting subjective experiences of water insecurity

It was the problem of applying existing frameworks for food insecurity to the case of water insecurity that motivated me and my colleagues to carry out exploratory research on household water access in rural highland Ethiopia. In this setting, access to clean, sufficient and reliable water is severely constrained: Water for all household uses was collected – almost exclusively by women and girls – from sources that were sometimes more than an hour's walk away; sources were subject to contamination from farm and livestock; and water was competed over (Stevenson et al. 2012). In the setting we studied, however, water was nonetheless common property: It was collected from springs, streams and ponds over which communities exercised informal claims, but the sources were not fenced, nor were any fees levied on users for access.

Building on the work of Amber Wutich in Bolivia (Wutich 2009; Wutich & Ragsdale 2008), we used qualitative methods to document a wide range of obstacles to secure water access in this setting, including time costs of water collection, disputes with husbands and neighbours over water, and the shame associated with not being able to keep oneself or one's children clean. Difficulties obtaining sufficient quantities of water for all household uses forced some families to breach norms of hygiene, propriety and hospitality – as, for example, when they found themselves unable to offer drinking water to guests. As one woman said: "When our children go to school, we send them with dirty faces."

Our approach was to combine these varied experiences – opportunity costs of water collection, strained relationships, as well as frank thirst and going without water – into a questionnaire that reflected local experiences. Responses to this questionnaire (summed scores reflecting the variety of such experiences in the past month) were significantly associated with responses to a standard scale of psychological distress (the WHO Self-Reporting Questionnaire), providing support for the scale's validity as a measure of water related stress or household water insecurity.

This approach to devising household-level water insecurity questionnaires has been replicated in Ethiopia (Hadley & Freeman 2016; Stevenson et al. 2016), and further developed in other parts of Africa (Bisung & Elliott 2018; Tsai et al. 2016; Workman & Ureksoy 2017) and in other world areas (e.g. Jepson 2014; Jepson et al. 2017; Tallman 2019). Studies that use water insecurity measures such as these represent an advance on studies that focus only on water quality or source types (as the MDGs did, with their focus on "improved" versus "unimproved" sources). Taking account of subjective experiences of deprivation makes sense because it is not only material deprivation that is harmful to health, but the experience of being chronically tantalized by what others enjoy (cf. Pickett & Wilkinson 2015; Sapolsky 2005). Like difficulty accessing food but more so, water insecurity implies lack of control over a fundamental condition for survival.

A logical extension of this program of research is to attempt to generate cross-culturally applicable scales of water insecurity, as scholars of food insecurity have done (e.g. FAO 2016). One such attempt, the Household Water Insecurity Experiences (HWISE) study, involves parallel studies in 27 countries (Young et al. 2019). Such comparative projects promise to shed light on important questions about household water insecurity – What are the most common access barriers? What characterizes the most insecure households? How is water insecurity bundled with other forms of deprivation? – which may help target those most in need of help. However, as Srinivasan and colleagues (2017) observe, water insecurity measures on their own don't necessarily tell us what kinds of intervention are warranted. Standard technological responses, such as drilling new boreholes or protecting community water supplies, may not necessarily resolve water insecurity for those most in need. An episode from our follow-up study on household water insecurity in northern Ethiopia is instructive in this regard.

2. Infrastructure change, small scale: Village water improvements

The second study my colleagues and I carried out in Ethiopia sought to test the utility of a household water insecurity survey as a way of measuring the impacts of an intervention to improve water supplies. In partnership with Catholic Relief Services, an NGO that carries out water improvement projects in Wello, we designed a study that would assess subjective household water insecurity in intervention and control communities both before and after water improvement projects were carried out (Stevenson et al. 2016). The intervention involved erecting concrete housings around springs, which would protect them from contamination from farm-run off. (Figure 1: spring versus tapstand.) As in our previous study, this one focused on villages in an Amharic-speaking part of northern Ethiopia, the residents of which relied for the most part on springs and streams held as common property. Baseline and endline data collection occurred one year apart. Three study sites received water source improvement interventions; another two served as controls.

The survey results threw up some unexpected findings. Although the villages that received source protection saw significant declines in water insecurity, there was no evidence of an independent effect of the intervention on women's psychological distress. And at endline, nearly a quarter of households in the intervention sites were still using water from unprotected sources. The survey data themselves provided little indication as to why this should be.

A clue came from the qualitative part of the fieldwork. During fieldwork for the follow-up study we discovered that the water improvement projects that formed the focal intervention were accompanied by a governance system that threatened to exclude some of the alleged beneficiaries of the project. Water committees had been set up, and whereas the springs had been freely accessible around the clock, the new waterpoints wouldn't be. Once the concrete housings and tapstands were installed, one committee member told us, "We will build a fence around the water point, and decide with the community to use it from 6am to 10am. If we leave it open the whole day it will be out of use in a very short time."

An intervention such as this – in which a spring is protected from potential contamination, but also becomes fenced, and the time for using it restricted – is a mixed blessing. For some, the protection afforded by the new housing may be recognized as substantial progress, more than justifying the new, shorter opening hours; for others, however, the risk of contamination may rank lower in their priorities than the convenience of having water freely available 24/7. Compounding this, in a majority of cases the newly formed water committees charged user fees, with which to hire a guard and to cover maintenance costs. For those already struggling to feed themselves, such fees may be prohibitive.

When the trade-off between protection and access was taken account of, other aspects of the communities' attitudes to the intervention made more sense. Testimony from communities that had not yet received water source improvements suggested ambivalence. Some were enthusiastic about any investment by the NGO ("Water protection means less disease. We'll be healthier and work more efficiently."). Others expressed doubts about the need for intervention at all. ("Our water situation is fine. We have no problem.").

Whereas the enclosure of the springs was supposed to benefit everyone by protecting water from microbiological contamination, in fact the new governance model reconfigured the community who had access to the springs. This process plausibly explained the continued use of unprotected water sources after the intervention, and the failure of the intervention to alleviate women's psychological distress. The mixed outcomes of this water intervention at the village level foreshadow some of the impacts of much larger schemes.

3. Infrastructure change, large scale: River basin engineering

River basin engineering projects serve as an archetypal example of how resources formerly treated as common property – free-flowing rivers – can be captured and repurposed. As in smaller scale projects, the case for intervention is often made on the basis of a deficit model: The new infrastructure is supposed to provide something that is lacking, such as a more regular supply of water for irrigation, or the added benefit of electricity. Despite overwhelming evidence that large dams are a poor investment in economic, human, and environmental terms (Goldsmith & Hildyard 1984; McCully 2001; Scudder 2005; Ansar et al. 2014), however, large dams continue to be built apace.

Beginning in the 19th century, engineers from Britain and other countries devised new techniques of river basin engineering in the context of imperial projects in Africa and Asia. In Egypt, the raising of the Aswan dam controlled the flow of the Nile in ways that served the interests of expanding cotton plantations, and at the same time suspended a natural flood pulse to which indigenous farming systems were attuned (Butzer 1976; Mitchell 2002). In India, similarly, planners devised engineering interventions that would do away with annual floods, in the process depriving farmers who depended on them for harvests (D’Souza 2006). As D’Souza argues, the very concept of *flood* was redefined by colonial authorities: Rather than being a regular and more or less predictable aspect of seasonal change in floodplain Orissa, it was reinvented as a hazard or a disaster – something to be eliminated.

For several years, my colleagues and I have studied the implications of large dams for the people and ecosystems of Ethiopia’s River Omo. The Omo was until the 21st century a free-flowing river; its damming represents a textbook case of trade-offs in river-basin development (Hodbod et al. 2019; Stevenson 2018). The Gibe III dam in the middle reaches of the Omo, completed in 2015, reportedly doubled Ethiopia’s electricity generating capacity, and regulated downstream flows in ways that facilitate plantation agriculture (Kamski 2016). On the cost side of the ledger, however, must be counted not only the massive fiscal expense of the project, estimated at $1.6bn (Salini 2016), but the human and environmental impacts of the dam. Fisheries biologists predict that suspension of the annual flood will cause the collapse of the fish populations of Lake Turkana in Kenya, into which the river drains (Gownaris et al. 2016; cf. Avery 2013; anonymous 2013). Others have forecast the degradation of riverine forest and grazing land (Carr 2017). Our work has focused on the implications of the end of the flood for indigenous farming systems in the Lower Omo.

Flood retreat farming is a technique that relies on the annual flood of rivers to provide irrigation water. It has been practiced in many river basins in Africa, including the Nile, Awash, Niger, and Zambezi (Everard 2016). In the terminology of some scholars, the practice belongs to an “eotechnic stage” of irrigation (literally ‘dawn-technology’; Hamdan 1961, cf. Mumford 1934), suggesting that it is a relic of the distant past, or a first step towards more sophisticated types of irrigation. Belying this terminology, however, it is in fact highly productive relative to investment of labour: River floods, and the silt that they carry, provide a pulse of water and nutrients that make it possible to grow crops reliably, year after year, without artificial fertilizers, even in arid environments with erratic rainfall regimes (Adams 1992). Floodplain farming systems also permit intensive agriculture to be carried out alongside a host of other livelihood activities, such as fishing, that depend on free-flowing rivers (Matsuda 1996).

In the Lower Omo, access to strips of land along the river, which were reliably inundated by the flood were (unlike grassland or land where rainfed farming was practiced) formally recognized as family property, with ownership passed from father to son. However, no family could mobilize enough labour to make use of the entirety of the land they owned. “In theory rights of control and allocation of river-bank strips are powerful but in reality they are limited,” wrote Almagor, an anthropologist who studied flood retreat farming among the Dassanech of the Omo delta in the 1970s. “[B]y custom a request for a vacant strip cannot be refused” (Almagor 1978: 45). Strips of riverbank would therefore be allocated to others on a seasonal basis, and in practice there was little variation in size among the farmed plots.

The Nyangatom, the immediate neighbours of the Dassanech, among whom my colleagues and I have worked, observed a similar system of land allocation. Formally, family ownership of riverbank land was recognized, but practically anyone who wished to cultivate land along the river could obtain access to a plot. The viability of the farming system, however, depended entirely on the flood. After the Gibe III reservoir was filled in 2015 and the flood ended, floodplain farming was rendered obsolete. (Figure 2: Gibe III dam and riverbank farm after the end of the annual flood.) Pertaub and colleagues (2019) describe the economic impacts for one family.

> In the dry season of 2012-2013, L.T. and his family cultivated on the bank of the Omo following the annual flood. Altogether they harvested 17 sacks of sorghum, two sacks of maize and two and a half sacks of cowpeas. They also obtained around 400 chunks of tobacco, 50 squash and forty calabashes from their river gardens that year. [After the completion of the Gibe III dam] in 2018 the family obtained no harvest at all. Although they attempted rain-fed farming in the wet season, the crop was destroyed by locusts.

To use a phrase from Smith (2010), projects such as Gibe III dam *capitalize* water, turning it from a natural resource to which access is allocated through local networks of kin and friendship, to a form of capital that can be monopolized by a few (cf. Parr 2010). The process also involves transformation in the uses to which water is put: in the case of large dams this is typically a change from complex ecosystems and diverse forms of livelihood, to a simplified ecosystem managed by a centralized authority in the interest of producing electricity and cash crops (Stevenson & Kamski, in press). The capitalization of water leads to the de-capitalization of countless people. Large dams provide “windfall economic rents, generated by the exploitation of natural resources” that were hitherto common property (Cernea 2008: p. 93). Typically these rents or profits are not shared with the people whose livelihoods are negatively impacted. Rather than speaking of them as a “windfall”, we might do better to speak of them as a transfer of wealth from one group to another.

Discussion and prospects

I opened this essay with a note on the complexity of water security as a construct, and the difficulty of measuring it in ways that are faithful to human experience. Unlike in the case of food, access barriers for water cannot be assumed to correspond to market prices. An approach to assessing water insecurity that has gained ground over the past decade focuses on subjective experiences of insecure access to water at the household level. This represents a significant advance, with potential to improve identification of the most needy and to inform targeting of water interventions. But studies of subjective household water insecurity so far provide a mainly static picture: snap-shots of the distribution of water insecurity in study communities at a given time. In this essay I have tried to extend this research agenda by attending to situations where arrangements for water access are being transformed through infrastructural interventions.

This is an exploratory project, and the material that I have presented illustrates some of the challenges involved. Expanding inquiries into water insecurity across time and space requires us to jettison convenient assumptions about the ways communities arrange access to water. In studies of changes to household water supply, much hinges on the arrangements for water access that exist prior to intervention. In the settings we studied in northern Ethiopia, springs and streams had been treated largely as common property; in other settings, household or family ownership – "self supply" from private wells – may prevail, or exist alongside communal ownership (Adank et al. 2013). Research in urban settings such as Nairobi demonstrates how municipal water services are contested, and sometimes undermined, by citizens' efforts to secure access for themselves (Schramm & Ibrahim 2019). The best route to understanding these dynamics is to supplement longitudinal surveys with extensive ethnographic research on water governance.

In the case of large dams, the question of how to measure insecure access to water is challenging because the rivers blocked by dams provide multiple services for people and ecosystems. Rivers not only provide water for drinking and washing but also underpin food systems. The principal metric we used to assess the insecurity brought about by the Gibe III dam is sacks of grain – a measure of the size of foregone harvest. This, however, only scratches the surface of the impacts of the dam, which might with equal justification be measured in decline in the abundance of fishes in the river, or the psychological disturbance associated with increasing hunger, or the experience of having your homeland degraded around you.

To what extent are negative outcomes such as those I have described here a necessary result of infrastructure change? Must projects like these have such inequitable outcomes? An historically informed assessment demonstrates that infrastructural change can often magnify existing inequalities. Negative outcomes are not, however, foregone conclusions, and it is worthwhile to attend to the space available for social manoevre in different kinds of projects.

In the case of small-scale infrastructure projects, governance can make a difference. Village water committees can operate a sliding scale for upkeep fees, and may exempt the most needy from payment (cf. Chaka et al. 2011; Cleaver 2012). Fees imposed by water committees in Ethiopia vary – monthly fees in a sample of 89 water schemes studied by Alexander et al. (2015) ranged from 0.4 to 10 Birr (0.02-0.53 USD) – but it is unclear whether this variation corresponds to communities' capacity to pay (Kelly Alexander, personal communication, 2019). A comparative study in Namibia demonstrated that arrangements may vary according to the degree of state involvement, with a more equitable "payment according to usage" system more common in communities with closer monitoring by the state, and a less equitable “all members pay the same” system more common in those where state regulation had lessi purchase (Schnegg et al. 2016).

In the case of hydroelectric dams, revenues from the sale of electricity could feasibly be redistributed among stakeholders in such a way that those for whom the projects were most costly (in lost property or livelihoods) would receive most support. Such a system would be consistent with the recommendations emerging from the World Commission on Dams (2000), and the “risks and reconstruction” framework developed by Michael Cernea (2000). The historical record, however, provides scant evidence of such arrangements. In Scudder & Gay’s analysis of the resettlement outcomes of fifty large dams, in only eight cases were prior living standards maintained, and in only three cases did resettlement raise living standards (Scudder 2012: 47). Since downstream populations are rarely considered in the early stages of project planning, they are even less likely to receive compensation than are those who have been forced to move by the creation of reservoirs (Richter et al. 2010). Although large dams need not logically lead to impoverishment, in practice they usually do.

Could attention to the institutional dimensions of infrastructure projects help improve the equity outcomes of water interventions? If the risks inherent in infrastructural change are borne in mind and safeguards are put in place, then the answer might be Yes. Often, however, planners take a partial view of the institutional landscape, in which the prerogative of those in power to harness water resources for economic growth is taken for granted, and harms inflicted in the process are disregarded. Getting the “institutional plumbing” right is too often equated with striking the right balance between management expertise and bricks and mortar (Parker et al. 2016). Missing from this picture are the multiple overlapping claims that are made on water within any polity, deriving from multiple sets of institutions, and oriented towards different visions of prosperity.

Water seems to subvert dominant ideological models of how natural resources ought to be. It cannot easily be owned; it resists categorization as a commodity, and yet access to it can be controlled or constrained through infrastructure and techniques of governance. Technologies that enable storage and measurement of water support claims of ownership; by the same token they may overturn prior access arrangements (Bakker 2003, 2011). Large dams are just the most conspicuous example of this process: by concentrating large quantities of water in a single location and controlling downstream flows, they concentrate power and redraw the boundaries of the communities on whose behalf water is managed. Small-scale community water improvement projects may work in similar ways. To the extent that water security studies neglect the social and political implications of infrastructure, they forfeit a great opportunity.

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Figure 1: water collection at a natural spring (left), and at a standpipe (right) in Wello, northern Ethiopia

Figure 2: The Gibe III dam (left); woman and child at a former flood-retreat farm plot in the Lower Omo, April 2019 (right)

Water access is more challenging to systematize than access to food.

Physical infrastructure for water protection, treatment and transport plays an important role in mediating water access.

Claims to water ownership or access are often secondary to claims to use of infrastructure.

Moments of infrastructural change provide opportunities for renegotiating access to water.

When the potential for exclusion inherent in infrastructural changes are disregarded, infrastructure interventions can have substantial negative impacts on water security.